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Guiding Principles For Sustainable Humanitarian Engineering Projects

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Abstract

Over the past ten years, engineering students and professionals in the United States have shown a strong interest in directly addressing the needs of developing communities worldwide—a field that has traditionally been in the hands of international development organizations. That interest has taken the form of short- and medium-term international trips through Engineers Without Borders–USA (EWB-USA) and similar organizations. This kind of outreach work has been integrated into engineering education at the University of Colorado at Boulder. This paper addresses the challenges and opportunities associated with balancing two goals in engineering for humanitarian development projects within an academic context: (i) effective sustainable community development, and (ii) meaningful education of engineers. Guiding principles necessary to meet those two goals are proposed.

Introduction

International development has traditionally been conducted by expert professionals in large, well-funded organizations (UN, World Bank, USAID) or by volunteers working for non-governmental organizations. The large-scale participation of engineering students and professionals in international development is a new phenomenon over the past ten years, as demonstrated by the vigorous growth of Engineers Without Borders (EWB) organizations in the US (http://www.ewb-usa.org) and abroad (http://www.ewb-international.org).

The work of EWB falls into what Bugliarello (2008) refers to as "engineering for development," a new interdisciplinary thrust in engineering which "…responds to the global need for engineers who understand the problems of development and sustainability, can bring to bear on them their engineering knowledge, are motivated by a sense of the future, and are able to interact with other disciplines, with communities and with political leaders to design and implement solutions." More specific to the developing world, "engineering for humanitarian development" contributes in part to the implementation of the eight Millennium Development Goals (United Nations 2003) and represents an alternative to top-down

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development as usual. It is a grassroots movement consisting of individuals who are willing to donate time and expertise to solve poverty issues. The projects are smaller in size and funding than traditional engineering projects and do not compete with those conducted by large engineering firms.

Since 2004, engineering for humanitarian development has been the main emphasis of the Engineering for Developing Communities (EDC) program at the University of Colorado at Boulder (http://www.edc-cu.org). The program was recently renamed the Mortenson Center in Engineering for Developing Communities (MC-EDC). It promotes integrated and participatory solutions to humanitarian development by educating globally responsible engineering students and professionals to address the problems faced by developing communities worldwide. MC-EDC recognizes that community development requires an integrated approach, bridging across disciplines such as engineering/technology, public health, social entrepreneurship, public policy, and security. MC-EDC also acknowledges that engineering for humanitarian development, within the academic context, needs to balance two basic goals: (i) effective sustainable community development, and (ii) meaningful education of engineers. Based on our own experience with MC-EDC and EWB-USA projects, we present below guiding principles to reconcile those two goals.

A Continuum of Engagement

Today, the participation of engineering students and volunteers on real projects in the developing world takes a number of forms, ranging from short-term experiences, sometimes called voluntary tourism, to long-term living situations like study abroad, internships, and Peace Corps service. These are two extremes in a continuum of engagement that ranges from weeks to months or years. To be effective, that engagement requires a set of guiding principles to make those experiences a success for both the students and the participating organization or community hosting the students.

Experts in international development have a wide range of opinions regarding the effectiveness of trips, based on their duration. Some argue that short trips accomplish nothing, while others argue that long trips create a culture of dependency. Suchdev et al. (2007) discuss various arguments used by critics of short-term medical missions. They can be paraphrased as follows:

- Self-serving: Short-term medical missions are of value to the volunteers but do not address the needs of the community. Volunteers often declare victory too soon and move on to the next experience.
- Raising unmet expectations: The volunteers have limited skills and experience to meet the expectations of the community. The community receives less than what the volunteers make them believe they will.
- Ineffective: The volunteers provide band-aid solutions to the community problems that are not long lasting. They do not have time to comprehend the community dynamics and the complexity of the problems or to engage community members in problem identification and resolution.
- Imposing burden on local communities and facilities: The community may have different challenges and priorities than those identified by the volunteers. Further, hosting volunteers may create an added burden on limited community resources.
- Inappropriate: The volunteers fail to provide quality services and programs and those provided are out of touch with what the community needs.

- Unaccountable: Once the volunteers leave, there is no one in charge and projects fail.

In addition to this list, critics also suggest that grassroots efforts can have limited impact by virtue of demanding lengthy interaction and attention from highly experienced development professionals or, at worst, can have a negative impact on the community and be a waste of local and international resources while presenting the appearance of progress.

There are many instances where such arguments are valid for missions conducted by volunteers from rich countries into resource-poor countries. This can apply to charity organizations, which, despite good intentions, rarely make special efforts to understand the breadth of community needs or do not have the range of expertise required to address those needs. But to generalize such criticisms to all types of international missions is not appropriate. Indeed, the aforementioned criticisms may not hold for short- and medium-term engineering for humanitarian development trips if proper guiding principles are followed and a multi-year commitment is established beforehand and is well maintained.

It is noteworthy to reflect on the goals of engineering project-based international development activities within an academic context. The first goal must be community development and capacity building. This is done by partnering with the community to address its problems and needs and then devising long-lasting, successful solutions that are respectful of the community itself, its people, and its environment. The desired outcome is to create healthy and safe communities. The mindset necessary to reach the first goal can best be described by a quote attributed to E.F. Schumacher: "Find out what people do best and teach them to do it better" (1973). A set of objectives can be outlined through proper assessment of community needs and existing capital.

The second goal relates to the benefits gained by engineering volunteers. For students, the goal is educational in nature, allowing them to have an international experience, an opportunity to work on a real project from concept to implementation, and an opportunity to experience multicultural teamwork. For engineering professionals, the goal is more altruistic, but at the same time, may allow them to share their expertise, mentor engineering students, and recruit student leaders who will later work in engineering firms. All those features closely match what is expected today of engineering education by the Accreditation Board for Engineering and Technology (2007) and the recommendations by the American Society of Civil Engineering (ASCE) Body of Knowledge for the 21st Century (2006).

Guidelines for successful engineering project-based international development volunteer activities must be developed. Those guidelines must balance the two aforementioned goals while also acknowledging the complexity of international development, which has the following characteristics:

- The field of international development is diverse, multidisciplinary, and not unified. It has had its share of successes and failures over the past fifty years (Easterly 2006). Many best practices have been developed by various agencies, yet little effort has been made to develop a comprehensive database of such practices.
- No two development projects are alike, although similar issues may appear from country to country. The communities being addressed range in geographical scale (villages to megacities) and time scale (transient to permanent communities). Even within a single country or region, one-size solutions do not fit all.
- There is no such thing as one model of international development or one model of intervention. During the lifetime of a project, there are points when short-term interventions are adequate and others when a more long-term presence is necessary. After all, this variability exists in all projects

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regardless of location. The models of intervention must best fit the community's current phase of development (e.g., emergency response, recovery, development).

In engineering for humanitarian development, the challenge is to cultivate a repertoire of best practices (assessment, design, implementation, evaluation, and follow-up) or guiding principles that could be used by the engineering profession. Ideally, those principles could be applied to different settings (developed vs. developing communities) rather than trying to duplicate solutions that claim universal applicability. The guiding principles can be derived from experience in successful projects from industrialized countries and in previous international development projects.

EWB and MC-EDC Projects

Both EWB-USA and the Engineering for Developing Communities (EDC) program originated from the College of Engineering and Applied Science at the University of Colorado at Boulder (CU-Boulder). EWB-USA grew out of a single project run by the first author and a handful of undergraduate students in 2001. Today, EWB-USA is well established, and its volunteers are involved in projects in forty-five different countries. Although the organization is currently expanding its educational component, its focus is on completing community development projects.

The MC-EDC program was born out of the realization that students scheduled to participate in EWB-USA projects needed technical and non-technical preparation and skills. A program of study was therefore developed to educate students in sustainable community development and appropriate technology. MC-EDC addresses a wide range of issues including water provisioning and purification, sanitation, public health, power production, shelter, site planning, infrastructure, communication, and jobs and capital for developing communities including villages, refugee settlements, and Native American reservations. Whereas EWB-USA focuses on extracurricular outreach projects, MC-EDC places equal emphasis on education, research/development, and service/outreach and, more importantly, on the relationship between those three components.

The discussion below focuses on two types of field projects that involve engineering students, faculty, and professional mentors at CU-Boulder: service/outreach projects conducted by the CU-Boulder student chapter of EWB (EWB-CU) that follow the guidelines set forth by EWB-USA and tend to be extracurricular; and MC-EDC projects that often have a significant research or educational focus.

EWB-USA projects

Since 2001, nearly 100 CU-Boulder engineering students have participated in EWB-USA-sponsored projects in Belize, Mali, Thailand, Senegal, Mauritania, Rwanda, Peru, and Nepal (http://ceae.colorado.edu/ewbcu). Their work is usually done on a voluntary basis over the course of one or several academic years. Students go to the field one or two times a year and work on their respective projects between trips. They are responsible for project assessment, design (which is reviewed by professional mentors), fundraising, project management, implementation, and follow-up. As per the guidelines suggested by EWB-USA, the chapter must show a five-year commitment to each community it is serving.

It has been our experience that students have benefited from EWB projects in multiple ways. In general, such projects:

1) Give the students an opportunity to experience all aspects of engineering: problem identification, assessment, design, funding, implementation, and monitoring.

2) Give the students an opportunity to work with professionals and real clients, develop good contacts within industry, and learn by doing.

3) Provide the students with a direct hands-on experience in a safe environment.

4) Give the students the opportunity to work in teams on larger and more socially relevant projects than the traditional design competitions featuring concrete canoes (in civil engineering) or the new flushing toilet (in mechanical engineering).

5) Show the students that engineering problems can be complex and not always well-defined, can be solved in more than one way, and often require working effectively with people who think differently (including engineers and non-engineers) and have different cultural backgrounds.

6) Teach the students how to interact with different cultures and think "outside the box" with limited tools.

7) Train the students to develop awareness of professional ethics and the role that engineering plays in addressing community needs.

EWB-USA projects are voluntary and not usually integrated into the engineering curriculum. However, they often reveal critical development issues that might serve later as research ideas for undergraduate independent studies or master's degree research topics at CU-Boulder. In some cases, the projects can be integrated into engineering senior design classes.

MC-EDC projects

Other projects unrelated to EWB-USA have been underway at CU-Boulder since 2004. These MC-EDC-sponsored projects all contain overlapping education, research, and outreach components. They tend to cut across disciplines such as engineering, business, and public health and are often funded through multi-year grants. As is the case with EWB-USA projects, the MC-EDC makes a long-term commitment to its partner communities. Project examples include:

- Use of fuel briquettes made from municipal waste for heating and cooking in Afghanistan. The Afghan project is conducted in partnership with two NGOs, Afghans for Tomorrow and the Foundation for Sustainable Technologies (FoST) in Nepal. Research topics derived from this project include indoor air pollution, optimal briquette composition for maximum combustion, and social entrepreneurship.
- Tele-education and tele-medicine project in the Amazon region of Peru. The project has been supported through the CU-Boulder Outreach Committee. Educational and research topics derived from this project include telecommunications system design and the use of information and communications technology to encourage sustainable rural development.
- Sustainable economic development project with the Crow Nations of Montana in collaboration with the US Department of the Interior Division of Energy and Mineral Development. The project focuses on using compressed earth blocks and earthen building methods for construction of single-family homes and encourages the development of tribal construction and construction-related businesses.
- Expansion of the Casa de la Esperanza facilities in Longmont, CO. Casa is a Boulder County Housing Authority (BCHA) managed community of agricultural workers located approximately twenty miles northeast of Boulder. As a class project, graduate engineering students have helped the community with the architectural design of an expanded science and math center and completed a community needs assessment.

Guiding Principles

These project activities have helped us derive guiding principles to balance effective sustainable community development with the education of engineers using humanitarian development projects as a

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framework. The guiding principles were adapted from those proposed by Suchdev et al. (2007) and Heck et al. (2007) for medical missions.

Shared mission, vision, values, and approach

The effectiveness of field projects requires that all participants be reminded of the sponsoring organization's mission, vision, values, and approach to development. The students, faculty, and professional advisors need to understand that their work includes both a community development goal and an educational goal. They should also be reminded that humanitarian engineering for development is not charity work or tourism, but is instead a discipline dedicated to implementing sustainable solutions to community problems. The ultimate goal is to help create a healthy and safe community that can manage its own future without additional outside assistance.

Quality control and ethics

The melding of education with volunteerism can lead to sub-standard results if quality control and technological appropriateness are not primary guiding principles. Instead of encouraging the idea that short-term projects are an appropriate substitute for painstaking intervention, volunteer-based organizations must ensure quality control on every project, putting quality above quantity, and reminding all participants that the main goal is to create something sustainable that can be maintained and reproduced by the community.

Volunteer participants must also understand that they are bound to a professional code of ethics with regard to behavior, accountability, quality control and quality assurance, and delivery of projects. Although this is not often emphasized strongly in engineering education, it is nevertheless a given at the professional level. Work in developing communities requires the same level of standards and ethics as in developed communities. EWB-USA has adopted the code of ethics set forth by the American Society of Civil Engineers (ASCE) that provides fundamental canons, rules of practice, and professional obligations (2008). Engineering students who perform development work with varying levels of direct oversight sometimes face difficult ethical decisions with regards to the work they are doing and the limits of what they are fully trained to be doing independently. To ensure project design quality, all EWB-USA projects follow a rigorous process of submission and review by professional engineers.

Organizational accountability

While most humanitarian development organizations are established with sincere altruistic motivations, their structure can sometimes conflict with true development ideals. Specifically, volunteer-based organizations are often driven by the motivations of their current volunteer labor force and those volunteers tend to want to experience an immediate return on their efforts. Since encouraging volunteers to donate their time to painstaking and sometimes boring long-term projects is difficult, often a shotgun approach is used—focusing on the initiation of a variety of projects without regard for long-term sustainability of implemented solutions. This approach leads to varying levels of project completion and success. Even when the programs are based on long-term commitments to communities, volunteer turnover frequently results in the atrophy of many projects that are underway but not yet sustainably completed. Project leaders must be directly accountable for successes and failures within projects. This accountability remains regardless of management and engineer turnover, in the same way that traditional engineering firms are responsible for successful completion of their contracts.

Education

Education of both the volunteers and the community members is an integral part of humanitarian development projects. Students and working engineers need to acquire proper training before going on project trips. Ideally, this educational component should be integrated into the engineering curriculum, as is the case with the MC-EDC program. In time, an integrated curriculum would somewhat mitigate the need for additional training of professional engineers because, in theory, they would all be knowledgeable about the requirements and considerations necessary for this type of work.

Undergraduate Education

As discussed in another paper by the authors (Amadei and Sandekian 2009), MC-EDC brings together a wide range of courses in engineering, sustainability, appropriate technology, renewable energy, public health, international education and development, business, and various fields in the humanities. An EDC track was created in the Civil Engineering (CE) undergraduate curriculum in 2007 and a college-wide certificate program has recently been proposed. These options allow undergraduate students to enroll in a traditional engineering degree program at CU-Boulder and, at the same time, take some of their humanities and social sciences electives and technical electives or independent study credits in courses emphasizing sustainable community development. EDC projects could also be included in capstone courses for credit.

Graduate Education

EDC graduate tracks are currently approved within three of the six focus areas programs leading to MS and PhD degrees in Civil Engineering: Environmental Engineering (since 2004), Civil Systems (since 2008), and Construction Engineering and Management (since spring 2009). EDC tracks in the other CE programs (Building Systems, Water Resources, and Geotechnical Engineering) are under consideration by their respective faculty groups.

The guiding principle behind the EDC undergraduate and graduate tracks has been to integrate them into the current Civil Engineering curriculum by leveraging existing courses offered by the department, the college, or other units on campus.

Skills Training

Providing students with basic skills is as critical as providing the technical theory they get in the classroom. The first author has often observed excellent undergraduate or graduate students who, despite extensive engineering knowledge, are completely inept at manual work or managing a field project. To remedy that problem, the EWB-CU chapter and MC-EDC often jointly sponsor hands-on workshops during the academic year such as concrete design, health assessment methods, and photovoltaic design and installation. The workshops are optional and give the students much needed supplementary hands-on skills that they do not get in the classroom. Professional members also benefit from these trainings. Additional needed skills include language (at the proficiency level), culture, first aid, fundraising, management and leadership, and risk analysis (specifically regarding the development of evacuation and emergency response plans).

Community Education and Participation

Educating members of the partner community is a fundamental aspect of EWB-USA and MC-EDC projects. Concepts such as “train the trainers” or “teach the teachers” allow communities to be an integral part of the current development process while building capacity to solve their own problems. Methods of community education and participation are well documented, and include Participatory Action Research, Rapid Rural Appraisal, Rapid Assessment Methods, Behavior Change Communication, and others (Beebe 2001; Chambers 1983). The MC-EDC presents these methods in a two-semester graduate-level course entitled Sustainable Community Development (SCD). During the first semester (SCD I), the course emphasizes a public health perspective and participatory models, covering an overview of development and global health concepts and issues as they apply to developing communities. The second semester (SCD II) covers the principles, practices, and strategies of appropriate technology as part of an integrated and systems approach to community-based development.

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Innovation and technological appropriateness

Engineering for humanitarian development is still unusual in mainstream engineering curricula. In addition to teaching good engineering practices and design, educational efforts should encourage innovation that expands the usefulness of proven designs for direct applicability in resource-poor communities. Again, the primary driver for engineering innovation must be the end user. Volunteers must be encouraged to consider only those technologies that are truly appropriate for partner communities. Often that requires familiarization with existing and proven techniques. At the same time, volunteers should be discouraged from innovation simply for the sake of their own interest in the projects. A complicated new system design might be more exciting for volunteers, but a simple modification to an existing design is usually better for the partner community.

Fundraising

Humanitarian development projects require steady funding over multiple years, yet fundraising is a significant challenge for most organizations involved in this type of work. Approximately $30,000 is needed per year for each project run by the EWB-CU chapter, so students seek private donations or university-based funding sources.

MC-EDC projects require a different approach to funding, in part because they are integrated into an academic program. Faculty members apply for external grants that can be used to fund students who conduct research resulting in an independent study project, master's thesis, or doctoral dissertation. Faculty members also occasionally apply for, and receive, seed grants from on-campus resources. Typically, the seed grants provide early-stage project funding and are then leveraged to obtain external grants. The program's main funding challenge is finding the money to pay adjunct faculty to teach courses that are beyond the expertise of traditional engineering faculty, including public health and interdisciplinary development topics. Since the MC-EDC courses are mainly at the graduate level, they have small enrollments and, therefore, are not self-sustained by the small percentage of tuition dollars returned from the campus to the department.

The disclosure of dual goals, which include a balance between effective sustainable community development and the meaningful education of engineers, is critical for effective and honest fundraising and will put these projects in a separate category compared to those from traditional organizations. Unfortunately, the current funding structures for non-profit organizations encourage the constant development of "new" projects. Volunteers and donors are motivated by the news that new projects or those that have expanded to include additional communities impact greater numbers of people. These structures are often counterproductive to sustainable development because there is little or no incentive for employees, volunteers, or donors to ensure the success of previous projects, especially if they are currently struggling. As such, EDC projects in an academic context differ from conventional humanitarian development projects with regard to continuous fundraising and long-term community commitment.

Collaboration and teamwork

Successful humanitarian development projects require collaboration with various internal and external stakeholders and effective teamwork. EWB-USA and MC-EDC have advocated the need for creating a strong relationship with the community as well as with other partners such as government agencies, local NGOs, other local organizations (including local EWB groups, for instance), and individuals who live in the country but not necessarily in the partner community (including Peace Corps volunteers).

When dealing with student chapters, a critical issue is that of continuity. EWB-USA requires a five-year commitment to each partner community, which is slightly longer than the tenure of the average undergraduate engineering student. The project team must build on its members' skills and experiences,

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and continually assess its membership to ensure that new members are groomed to take over leadership roles as existing leaders graduate. Travel teams should include members with diverse specialties and not include extra (unnecessary) individuals simply because they have put in a lot of effort on the project.

Duration of intervention

The time that a project team spends in the partner community depends on the nature and the current phase of the project that is being addressed. Field visits are required to collect data, but it is much easier to evaluate alternatives and complete designs in a well-equipped office. Students have limited time for fieldwork during the academic year. Therefore, most implementation trips take place during academic breaks, with durations varying between one or two weeks and a couple of months, depending on the project phase (assessment, implementation, or monitoring). Designing interventions that fit what the community needs and match the visiting group's resources, involving several partners with each one visiting the community at a different time, and following well-established assessment methods such as Participatory Action Research can maximize the effectiveness of short-term interventions. The commitment to a partner community must be long-lasting and enduring, even if the duration of a project team's presence in the community is limited.

Sustainability

Project sustainability is one of the most difficult issues surrounding engineering for humanitarian development. People often ask, "How do teams ensure that what is implemented today will still be working six months, a year, five years, or ten years from now?" The answer to that specific question is, "They can't. Things change in the developed world, so how can anyone expect them not to change in the developing world?" With that in mind, the question should be, "How do teams ensure that what is implemented today can be modified and changed over time by the community without doing any harm or creating an unnecessary burden?" This implies a commitment to an ongoing collaborative relationship. Efforts can be augmented from trip to trip, and project scopes may change radically based on other development happening near the partner community.

Sustainability requires some period of external presence in the community, but not necessarily continuous presence. Requiring teams to make a multi-year commitment provides a strong tool for sustainability. Ultimately, however, the volunteer group needs to devise an exit strategy. If the team's capacity building efforts have been successful, the community should have the skills and desire to maintain, and possibly even expand, implemented solutions and have the knowledge needed to solve future problems that arise. Sustainability should focus on tangible capacity building, wherein partnerships with communities are sufficiently defined, cohesive, and accountable so that discrete projects are designed as stepping stones to address long-term goals.

Evaluation

The concept of evaluation instills fear into the minds of many individuals and organizational leaders. However, without this key component, it is impossible to determine the true success of any project. Standard methodologies for evaluating civil engineering projects, which typically are large-scale, long-lived projects involving many economic, financial, social, and environmental factors may or may not be directly applicable to these types of projects. However, those traditional methods provide a framework for the development of appropriate metrics of success. The MC-EDC is currently collecting samples of evaluation methodologies for incorporation into a best practices guide.

Conclusion

This paper highlights some of the work of the CU-Boulder student chapter of Engineers without Borders-USA and the Mortenson Center in Engineering for Developing Communities in an effort to identify

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guiding principles that balance the goals of effective sustainable community development and the meaningful education of engineers. The authors hope that presenting this list will initiate a conversation leading to refinements by others involved in similar efforts, eventually resulting in commonly accepted metrics for successful engineering for humanitarian development work.

The initiatives described herein can be fully integrated into existing engineering curricula, service/outreach, and research and development programs in modern engineering schools today. Such initiatives provide the students much needed field experience; create teamwork, leadership and global competency; and, above all, give students a global outlook, a sense of belonging and engagement, and a societal context for their work.

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